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Feed Potential of Sweet Potatoes in Hawaii

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ABSTRACT

The potential of using sweet potato tops and roots as economical feedstuffs in Hawaii was investigated. The results of the study indicated that the cost per ton of sweet potato roots has to be less than one-third the cost per ton of imported grains in order to be considered an economical substitute feed for either cattle or swine.

Sweet potato tops (leaves and vines) could become an economical feed for cattle if the price of imported alfalfa cubes or locally produced guineagrass cubes was to become 4.80 or 4.20 times higher, respectively, than the price of the tops.

INTRODUCTION

Most of the animal feeds used in Hawaii are imported from areas thousands of miles away. Because of continually increasing costs of importing feeds–especially with trans-Pacific transportation costs and the ever-present possibility of shipping strikes–of utmost importance to Hawaii's economy is the search for crops that can be planted in Hawaii to provide economically competitive feeds for livestock. The sweet potato (*Ipomoea batatas*) may have this potential. The root of the sweet potato is a potential energy source that could be substituted for grain, while the tops may possibly be used as a substitute for alfalfa and/or other roughages.

The objective of this report, therefore, is to analyze the economic potential of using both sweet potato tops and roots as feedstuffs in Hawaii. To accomplish this objective, this report is divided into two sections: the first reviews past research results in the use of sweet potatoes as a feed; the second section evaluates the economic potential of growing sweet potatoes as a feed for livestock in Hawaii.

REVIEW OF THE SWEET POTATO USED AS FEED

LEAVES AND VINES

The tops (leaves and vines) of the sweet potato, in terms of nutrient composition, have considerable potential as a cattle feedstuff (see Table 1). Results from a 3-year feeding trial at North Carolina Agricultural Experiment Station (1944) showed sweet potato vine silage in dairy rations to be as good as corn silage in maintaining body weight and milk production. Research by Seath et al. (1947) in Louisiana also indicated that feeding sweet potato vines as supplemental pasture for milking cows resulted in an increased milk production by an average of 19 percent over that from cows on permanent pasture. Research results from other countries (Kurihara and Imamura, 1959; Yamada et al., 1962; Gaspard and Hernandez, 1973) also have demonstrated the value of the tops. However, no in-depth economic analysis has been conducted to examine the feasibility of using the tops as an animal feed.

ROOTS

Judged by their nutrient composition, the roots of sweet potatoes should be a good energy source for most livestock species (see Table 1). In the United States around 1940, many plant and animal scientists conducted experiments on methods of growing and preparing these fleshy roots for feed. Edmond (1971) has summarized feeding tests for fattening steers, pigs, lactating dairy cows, and sheep.

Despite the fact that most of the research reports indicate that sweet potato roots are a relatively good feed, they, either in their raw form or in dried meal form, have not become important feedstuffs in providing readily digestible carbohydrates to animals (energy), even though sweet potatoes produce more carbohydrates per acre than corn (Ware, 1942). Buckman and Peete (1945) and Miller et al. (1949) concluded that dehydrated sweet potato meal does not possess enough of a cost advantage in comparison with corn because of the greater harvesting and processing costs due to the high water content of the root. The use of sweet potatoes as feed in the continental United States is

Table 1. Feed values of sweet potatoes

	Fresh roots[1]	Tops (vines and leaves)[1] as-fed basis
Dry matter, %	30.6	21.9
Ash, %	1.1	2.4
Crude fiber, %	1.3	5.9
Cattle digestion coefficient, %	N/A[2]	36.0
Ether extract, %	0.4	0.6
Cattle digestion coefficient, %	N/A	75.0
Nitrogen-free extract	26.2	10.2
Cattle digestion coefficient, %	N/A	72.0
Crude protein	1.7	2.8
Cattle digestible protein, %	0.3	1.8
Goats digestible protein, %	0.7	1.9
Horses digestible protein, %	0.7	1.8
Rabbits digestible protein, %	N/A	1.9
Sheep digestible protein, %	0.7	2.0
Energy[3]		
Cattle DE, Mcal/Kg	1.12	0.54
Sheep DE, Mcal/Kg	1.15	0.53
Swine DE, Mcal/Kg	1.08	N/A
Cattle ME, Mcal/Kg	0.92	0.45
Sheep ME, Mcal/Kg	0.94	0.43
Swine ME, Mcal/Kg	1.03	N/A
Cattle TDN, %	25.4	12.3
Sheep TDN, %	26.1	11.9
Swine TDN, %	24.5	N/A
Calcium, %	0.03	N/A
Chlorine, %	0.02	N/A
Iron, %	0.001	N/A
Magnesium, %	0.05	N/A
Phosphorus, %	0.05	N/A
Potassium, %	0.31	N/A
Sodium, %	0.01	N/A
Sulfur, %	0.04	N/A
Copper, Mg/Kg	1.3	N/A
Manganese, Mg/Kg	3.4	N/A
Ascorbic acid, Mg/Kg	218.6	N/A
Niacin, Mg/Kg	6.2	N/A
Riboflavin, Mg/Kg	0.6	N/A
Thiamin, Mg/Kg	1.0	N/A
Vitamin A, IU/g	91.6	N/A

[1]Values presented are on "as-fed" basis.
[2]N/A denotes not available.
[3]DE denotes digestible energy, ME metabolizable energy, TDN total digestible nutrients, and Mcal megacalorie. For discussion of feed energy, see page 0 of text.
Source: Atlas of Nutritional Data on United States and Canadian Feeds. National Academy of Sciences, 1971.

unlikely until processing costs are reduced and/or sweet potato varieties are developed that are adapted to mechanization in the same way as corn.

In Hawaii, Rosenberg and Seu (1952) fed sweet potato root meal to chickens as a substitute for yellow corn and found that uncured and uncooked dehydrated sweet potato root meal reduced growth rate. Curing and/or cooking the sweet potato meal improved the nutritional value; however, regardless of the method of preparation, sweet potato meal still significantly impaired the growth of young chicks in comparision with a corn-based diet.

In many Asian countries, sweet potato roots are and have been an important feedstuff (Villareal, 1975). For example, the economic value of sweet potatoes, in overall field crop production in Taiwan, is second only to the value of rice. Sixty-three percent of the roots harvested in Taiwan are used to feed animals (Cheng and Li, 1970). In the Philippines, 5 percent (1974–75) of the sweet potato root production is successfully used as an animal feed (Gerpacio, 1976).

FEED POTENTIAL

BACKGROUND

It has been speculated that the sweet potato was developed early in Polynesia and carried by the Polynesians to South America (Cooley, 1961). The sweet potato is usually assumed, however, to be of American origin (Dixon, 1932).

The history of sweet potato production in Hawaii is discussed in Chung's (1923) and Crawford's (1937) reports. They indicate that the ancient Hawaiians had considerable skill in the cultivation of this crop, that Captain Cook recorded finding the crop in 1778, and that there were indications the crop had been under cultivation in the Hawaiian Islands since A.D. 500.

The sweet potato was probably the main staple in the diet of the ancient Hawaiians, next to poi.[1] It is believed that they also used the sweet potato as a feed for hogs (Chung, 1923).

Sweet potato production gradually diminished as the percentage of the native Hawaiian population decreased. During World War I, a renewed interest in growing the crop arose in an attempt to make the Islands independent of imported animal feeds. It was used in place of barley and oats for farm animals and of wheat and corn for poultry. At one time (1917), about 350 acres of agricultural land in Hawaii were devoted to sweet potato cultivation. After World War I, imported feed again became economically available, and sweet potato acreage declined until about 1940, when only about 150 acres were harvested annually (Statistics of Hawaiian Agriculture, 1940).

Figures given in *Statistics of Hawaiian Agriculture, 1940–1977* indicate that, at the start of World War II, the annual sweet potato acreage had again increased and reached approximately 320 acres in 1946 and 1947. During this period, Elliott (1947) reported on the economic possibility of sweet potatoes as a feed crop and concluded the crop might be considered a good risk if feed prices remained near the high levels of that time over a long period. After this period, however, total acreage gradually

[1]Poi is a pasty, Hawaiian food made from taro root.

declined to a recent low of 48 acres in 1974, with the present being 95 acres (1977). Productivity per acre increased from 5600 lb/acre in 1947 to a high of 17,100 lb/acre in 1974. Total production declined from 2,470,000 pounds (1946) to a low of 550,000 pounds (1968), then moved up again to the present 1,190,000 pounds (1977). During this postwar period, sweet potatoes were used mainly as food, very little if any being used as animal feed.

The history of sweet potato production indicates that utilization of sweet potatoes as a feed declined after 1945 because imported feeds became economically available. No in-depth economic studies on the potential of raising sweet potatoes for feed were made because of a lack of accurate production data. Despite the facts that Hawaii has a tropical climate in which sweet potatoes grow better than in most temperate areas, and that imported-energy feeds must incur increasingly high transportation costs, efforts to promote sweet potato production for feed in Hawaii have had little success in the past. There is a need, therefore, to conduct an in-depth economic analysis to assess the relative economic potential of the sweet potato as a feed and to identify the problems that limit its utilization.

SELECTION OF FEED VALUE MEASUREMENTS

There are many ways to evaluate the feed potential of a particular crop; one is to use comparative feed energy values, of which several evaluation systems can be used. Total digestible nutrients (TDN) and other caloric energy utilization systems are used to measure a feed's energy value to the animal. The TDN method provides a system of energy evaluation that provides a relatively easy value to understand and work with. Digestion trials are run, and the TDN value is computed from digestible ether extract, digestible crude fiber, digestible crude protein, and digestible nitrogen-free extract and is expressed in terms of percentage, or pounds. TDN values for most feedstuffs are available, but this method has some shortcomings, especially as to evaluation of roughages. It tends to overvalue roughage, as compared with higher energy feedstuff such as the cereal grains (Cullison, 1975).

Net energy (NE) is the most accurate way of measuring the energy in a feed or of characterizing feed value. The NE system is probably the most precise measure of both an animal's energy requirements and the capacity of different feeds to meet the maintenance and production needs of the animal. The NE of a feed is that portion of the total energy in a feed that is available for useful work or productive purposes. However, actual NE values have been determined for only a limited number of feedstuffs, and NE values are presently not available for sweet potatoes.

Metabolizable energy (ME) is a slightly less precise measurement of feed energy value. ME is the portion of the gross energy consumed that is utilized by the animal for accomplishing work, including maintenance, growth, fattening, fetal development, milk production, and/or heat production (Cullison, 1975). It differs from NE in that it includes that energy lost as heat, which does no useful work for the animal. It is considered by many to be a more precise measure of a feedstuff's energy value to an animal than TDN values (Cullison, 1975). Thus, in this study, ME values are used in the calculation of relative economic feed values of the roots and the tops of sweet potatoes, since these are the most reliable energy values that are available for the sweet potato.

Imported barley, corn, sorghum, and wheat were selected as the feedstuffs for which sweet potato roots could be substituted in Hawaii or other tropical areas, while alfalfa cubes and guineagrass cubes were selected for substitution by sweet potato tops. The ME value of sweet potatoes, either on a dry matter basis (DMB) or on an "as-fed" basis, is compared with comparable ME values for the currently imported grains. This comparison was done for feeding of dairy cattle, beef cattle, and swine; the results are shown in Tables 2, 3, and 4.

Table 2. Comparative efficiency of feeding dairy cattle Hawaiian sweet potatoes and some imported grains

	Cost/ton[1] as fed ($)	Cost/MT[2] as fed ($)	Dry matter (%)	Cost/MT Dry matter basis (DMB) ($)	Metabolizable energy (ME) (Mcal/Kg DMB)	Cost/Mcal ME ($/Mcal)	ME (Mcal/$)
Barley, Pacific Coast, 46–48 lb, rolled	(159.80)	176.15	89	197.92	3.07[3]	0.064	15.63
Corn, dent, no. 2	(151.80)	167.34	89	188.01	3.43[3]	0.055	18.18
Grain sorghum (milo), California	(143.50)	158.18	89	177.73	3.02[3]	0.059	16.95
Wheat, Pacific Coast	(134.00)	147.70	89	165.78	3.31[3]	0.050	20.00
Sweet potato root, fresh	(120.00)	132.28	31	432.29	3.00[4]	0.144	6.80

[1]Honolulu market prices of grains in April 1977. Estimated production cost for producing the root is about $.06/lb, which was obtained from a typical sweet potato farm on Oahu. For a detailed explanation of the cost, see Huang and Marutani (1979).

[2]MT denotes metric ton.

[3]Nutrient Requirements of Dairy Cattle, National Academy of Sciences, 1971.

Atlas of Nutritional Data on United States and Canadian Feeds. National Academy of Sciences, 1971.

Table 3. Comparative efficiency of feeding beef cattle Hawaiian sweet potatoes and some imported grains

	Cost/ton[1] as fed ($)	Cost/MT[2] as fed ($)	Dry matter (%)	Cost/MT Dry matter basis (DMB) ($)	Metabolizable energy (ME) (Mcal/Kg DMB)	Cost/Mcal ME ($/Mcal)	ME (Mcal/$)
Barley, Pacific Coast, 46–48 lb, rolled	(159.80)	176.15	89	197.92	2.96[3]	0.067	14.93
Corn, dent, no. 2	(151.80)	167.34	89	188.01	3.29[3]	0.057	17.50
Grain sorghum (milo), California	(143.50)	158.18	89	177.73	2.93[3]	0.061	16.48
Wheat, Pacific Coast	(134.00)	147.70	89	165.78	3.18[3]	0.052	19.18
Sweet potato roots, fresh	(120.00)	132.28	31	432.29	3.00[4]	0.144	6.80

[1]Honolulu market prices of grains in April 1977. Estimated production cost for producing the root is about $.06/lb, which was obtained from a typical sweet potato farm on Oahu. For a detailed explanation of the cost, see Huang and Marutani (1979).

[2]MT denotes metric ton.

[3]Nutrient Requirements of Beef Cattle, National Academy of Sciences, 1976.

[4]Atlas of Nutritional Data on United States and Canadian Feeds, National Academy of Sciences, 1971.

Table 4. Comparison of feed value of sweet potato tops with other roughages fed to cattle

	Percentage water as fed (%)	ME on dry matter basis (Mcal/Kg)	ME on as-fed basis (Mcal/Kg)	Feed value index
Alfalfa cubes	10	2.35	2.11	4.80
Guineagrass cubes	10	2.05	1.85	4.20
Sweet potato tops	78.1	2.03	0.44	1.00

Source: Figures in columns 2 and 3 are obtained from Atlas of Nutritional Data on United States and Canadian Feeds. National Academy of Sciences, 1971. Publication No. ISBN 0-309-01919-2.

DAIRY AND BEEF CATTLE

Table 2 shows the comparative efficiency of using sweet potatoes and imported grains based on ME values of these feeds when fed to dairy cattle. In the first column of the table, the cost per ton of producing sweet potato roots as a feed is estimated for a typical sweet potato farm on Oahu (Huang and Marutani, 1979). It was estimated in their study that the cost of sweet potato production is around 6.22 cents per pound excluding the marketing preparation cost. It should be noted that sweet potatoes in the study were used for human consumption. However, when growing sweet potatoes for feed purposes, it could be expected that the cost per pound should be lower. Thus, 6 cents per pound was used in deriving the cost per ton figure in the table. As shown in Table 2, each Mcal of ME will cost a dairy farmer $0.144 if the root of the sweet potato is used as the feed. This cost is higher than the cost for each Mcal using imported corn, sorghum, or wheat. In other words, for each dollar spent, the dairy farmer received 6.80 Mcal of ME from feeding the sweet potato root to his cattle. This amount of energy is less than that received from a dollar's worth of any of the imported grains. (See the figures in the last column of the table.) Similar conclusions can also be drawn for beef cattle (Table 3).

Comparative economic feed values of imported alfalfa cubes and guineagrass cubes versus sweet potato tops are shown in Table 4. Figures in the last column of the table show that 1 ton or unit of guineagrass cubes has 4.30 times the feed energy of 1 ton or unit of sweet potato tops on an "as-fed" basis. This means that sweet potato tops could become an economical substitute for alfalfa cubes and guineagrass cubes if the price of alfalfa cubes is 4.90 times higher, and the price of guineagrass 4.30 times higher, than the price of sweet potato tops. This is true if the comparison is based solely on the ME of the different feedstuffs. This analysis does not take into account the higher local transportation costs per unit of dry matter of the high-moisture sweet potato tops versus the drier roughages. In April 1977, the prices of alfalfa cubes and of guineagrass cubes in Honolulu were about $152.58 per metric ton and $108.03 per metric ton, respectively. The imputed economic feed value of the tops was $31.52 per ton if substituted for the alfalfa cubes and $25.72 per ton if substituted for guineagrass cubes. As a byproduct of large-scale production of sweet potato roots, the costs of harvesting and processing of the tops as feed could be less than $25 per ton.[2] The potential of using the tops as cattle feed, therefore, is promising especially if it is the byproduct of root production.

Very little research has been conducted on the feasibility of using only the vines and leaves of the sweet potato as

[2]This estimated figure was obtained from a study in which the cost of harvesting post-harvest pineapple plants was calculated. The cost of harvesting pineapple plants was estimated (1976) at less than $25 per ton. To use this figure as the cost of harvesting sweet potato tops, it is assumed that the effort of harvesting sweet potato tops is the same as harvesting the pineapple plants.

Table 5. Comparative efficiency of feeding swine Hawaiian sweet potatoes and some imported grains

	Cost/ton[1] as fed ($)	Cost/MT[2] as fed ($)	Dry matter (%)	Cost/MT Dry matter basis (DMB) ($)	Metabolizable energy (ME) (Mcal/Kg DMB)	Cost/Mcal ME ($/Mcal)	ME (Mcal/$)
Barley, Pacific Coast, 46–48 lb, rolled	(159.80)	176.15	89	197.92	3.23[3]	0.061	16.33
Corn, dent, no. 2	(151.80)	167.34	89	188.01	3.81[3]	0.049	20.28
Grain sorghum (milo), California	(143.50)	158.18	89	177.73	3.66[3]	0.049	20.41
Wheat, Pacific Coast	(134.00)	147.70	89	165.78	3.73[3]	0.044	22.50
Sweet potato roots, fresh	(120.00)	132.28	31	426.71	3.35[4]	0.133	7.85

[1]Honolulu market prices of grains in April 1977. Estimated production cost for producing the root is about $.06/lb, which was obtained from a typical sweet potato farm on Oahu. For a detailed explanation of the cost, see Huang and Marutani (1979).
[2]MT denotes metric ton.
[3]Nutrient Requirements of Swine No. 2, National Academy of Sciences, 1973.
[4]Atlas of Nutritional Data on United States and Canadian Feeds, National Academy of Sciences, 1971.

Table 6. Comparison of feed energy values of sweet potato roots and of some imported feeds

	Dry matter (%)	ME DMB (Mcal/Kg)	ME as-fed (Mcal/Kg)	Feed value index
Dairy Cattle				
Barley, Pacific Coast, 46–48 lb, rolled	89	3.07	2.73	2.94
Corn, dent, no. 2	89	3.43	3.05	3.28
Grain sorghum (milo), California	89	3.02	2.69	2.89
Wheat, Pacific Coast	89	3.31	2.95	3.17
Sweet potato roots, fresh	31	3.00	0.93	1.00
Beef Cattle				
Barley, Pacific Coast, 46–48 lb, rolled	89	2.96	2.63	2.83
Corn, dent, no. 2	89	3.29	2.93	3.15
Grain sorghum (milo), California	89	2.93	2.61	2.81
Wheat, Pacific Coast	89	3.18	2.83	3.04
Sweet potato roots, fresh	31	3.00	0.93	1.00
Swine				
Barley, Pacific Coast, 46–48 lb, rolled	89	3.23	2.87	2.76
Corn, dent, no. 2	89	3.81	3.39	3.26
Grain sorghum (milo), California	89	3.66	3.26	3.13
Wheat, Pacific Coast	89	3.73	3.32	3.19
Sweet potato roots, fresh	31	3.35	1.04	1.00

Source: Figures in columns 2 and 3 were obtained from Nutrient Requirements for Dairy Cattle 1971, Beef Cattle, 1970, and Swine 1972, National Academy of Sciences.

feed. A study by Yamada et al. (1962) found the total yield of the top could be increased approximately 20 to 30 percent if the top were cut twice during the growth period. However, they also found that the root yield decreased about 30 percent by the cutting. Their findings indicate it is not economical to grow only sweet potato tops as cattle feed because the root has more economic value than the top. Increases in the production of the top, therefore, may not justify the economic loss due to decreases in the root production. However, whether it is economical to grow sweet potatoes in tropical areas mainly to use the tops as feed requires further study. Research, such as developing a new variety for leaf production or studying the effects of cutting leaves on root yield, is needed if use of the tops for animal feed is to become reality.

SWINE

The cost per Mcal of ME of feeding the sweet potato root to swine was $0.133, which is also higher than that of the imported grains (see the figures in the second column from the right in Table 5). In other words, for each dollar spent by a swine farmer, only 7.85 Mcal would be obtained, considerably less than that which can be obtained from imported grains, as shown in the last column of the table. No analysis of using sweet potato tops as swine feed was done due to the lack of published ME energy values for swine. It is believed the ME value of sweet potato tops for swine will be low as compared with other feeds, due to the relatively high level of indigestible fiber in the tops.

CONCLUSIONS

Table 6 gives a summary of the comparison of sweet potatoes with imported feeds. The figures in the last columns show the calculated feed value indexes of various imported grains fed to dairy cattle, beef cattle, and swine. The figures represent the relative feed values of various imported grains as compared with the feed value of sweet potato roots. For instance, the table shows that barley has 2.94 times the feed value of sweet potato roots for dairy cattle. This means that sweet potato roots could become an economical substitute for barley when the cost of 89 percent dry matter (DM) barley exceeds 2.94 times the cost of 31 percent (DM) sweet potato roots; that is, at the (April 1977) price of barley of $159.80/ton, the cost of the roots has to be $54.35/ton or less for roots to be an economical substitute.

The figures in the last columns clearly indicate that, in general, the cost per ton of sweet potato roots has to be less than one-third the cost per ton of imported grains in order to be considered an economical substitute for the imported grains used to feed cattle or swine. Currently (1977), the cost of producing sweet potato roots with 30.6 percent DM is approximately equal to the prices of imported grains with 89 percent DM. Therefore, unless there is a drastic increase in the prices of imported grains, or a substantial decrease in the cost of sweet potato production, use of the sweet potato roots as feed is not likely to occur.

Similarly, sweet potato tops could become an important feed for cattle if the prices of imported alfalfa cubes and guineagrass cubes were 4.80 times or 4.20 times higher, respectively, than the price of the tops. Currently (1977), sweet potato tops could become an economical feed for cattle only if they were a byproduct of sweet potato root production, with less than $25 per ton of harvest and handling costs chargeable to the tops. It is not economically justifiable to grow sweet potatoes mainly to use their tops as feed, with the present varieties and methods of production in Hawaii.

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